US008777161B2

(12) **United States Patent**
Pollock et al.

(10) **Patent No.: US 8,777,161 B2**
(45) **Date of Patent: Jul. 15, 2014**

(54) **LIGHTWEIGHT BLAST MITIGATING COMPOSITE PANEL**

(75) Inventors: **Clarence E Pollock**, Reynoldsburg, OH (US); **Mark J Perry**, Hilliard, OH (US); **John R Bush**, New Albany, OH (US); **Jeremy D Seidt**, Columbus, OH (US); **Michael L Fisher**, Granville, OH (US)

(73) Assignee: **Battelle Memorial Institute**, Columbus, OH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 853 days.

(21) Appl. No.: **12/989,917**

(22) PCT Filed: **May 4, 2009**

(86) PCT No.: **PCT/US2009/042677**
§ 371 (c)(1),
(2), (4) Date: **Oct. 27, 2010**

(87) PCT Pub. No.: **WO2010/033266**
PCT Pub. Date: **Mar. 25, 2010**

(65) **Prior Publication Data**
US 2011/0041679 A1 Feb. 24, 2011

Related U.S. Application Data

(60) Provisional application No. 61/071,516, filed on May 2, 2008, provisional application No. 61/071,517, filed on May 2, 2008.

(51) **Int. Cl.**
B64C 1/00 (2006.01)

(52) **U.S. Cl.**
USPC **244/121**; 244/118.1; 89/36.01; 89/36.11

(58) **Field of Classification Search**
USPC 244/118.1, 118.5, 121; 89/36.01, 36.02, 89/36.04, 36.11
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,241,187	B1 *	6/2001	Apel et al.	244/118.5
6,581,876	B2	6/2003	Cheung	
2003/0080248	A1	5/2003	Morgan	
2003/0114064	A1	6/2003	Fu et al.	
2005/0188825	A1 *	9/2005	Sharpe et al.	86/50
2006/0189236	A1	8/2006	Davis et al.	

FOREIGN PATENT DOCUMENTS

WO WO 2007/073055 12/2000

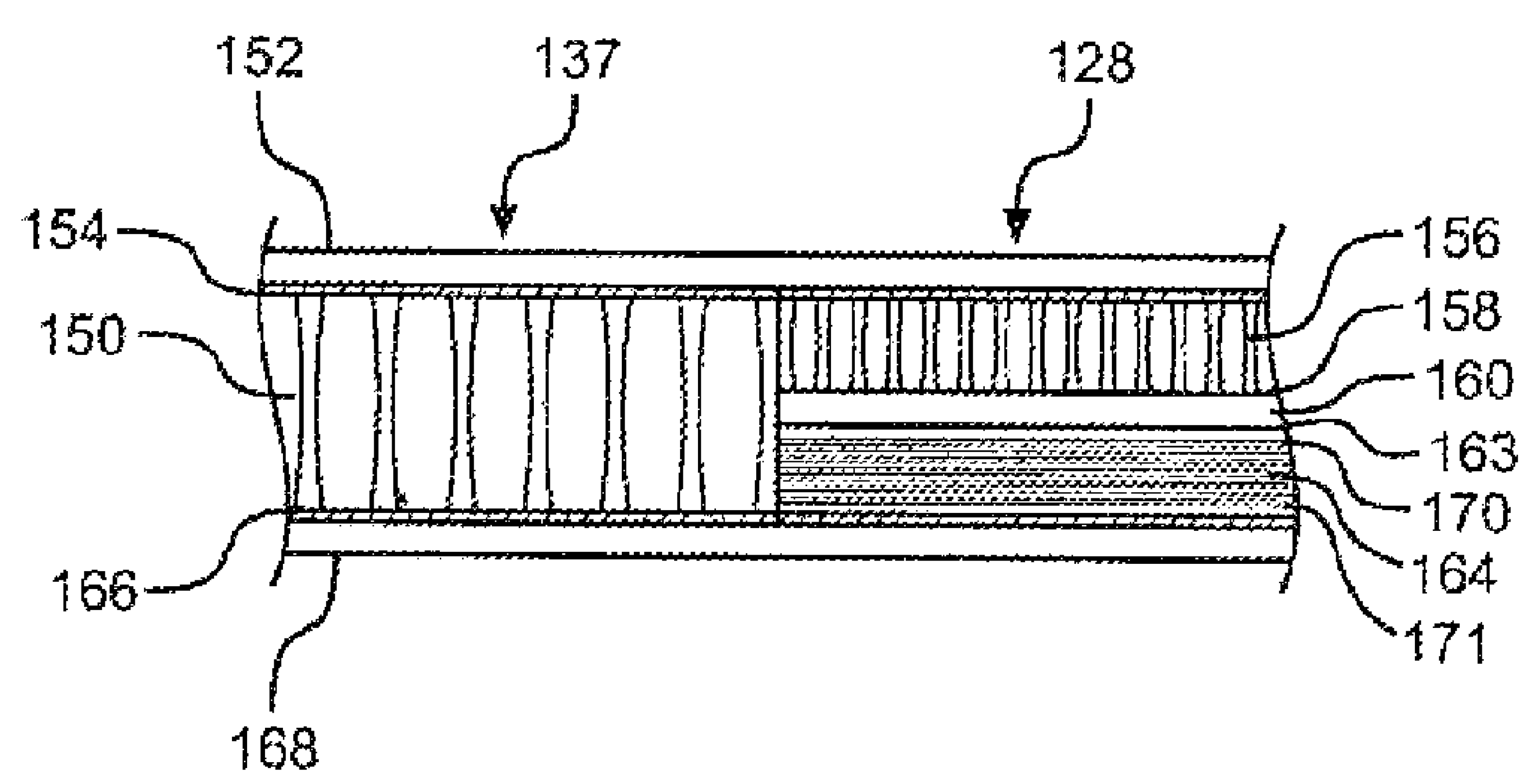
* cited by examiner

Primary Examiner — Timothy D Collins
Assistant Examiner — Nicholas McFall
(74) *Attorney, Agent, or Firm* — Diederiks & Whitelaw, PLC

(57) **ABSTRACT**

Lightweight blast mitigating composite panels (**10**) include a first glass composite shell (**14**; **152**), an intermediate, preferably honeycomb layer (**56**; **156**), a reinforcing layer (**60**; **160**), an ultra high molecular weight polyethylene fiber (UHMWPE) layer (**64**; **164**) and a second glass composite shell (**15**; **168**) adhered together with fire resistant adhesive layers (**54**; **58**, **63**, **66**; **154**, **158**, **163**, **166**). The UHMWPE layer (**64**; **164**) includes top and bottom coatings (**70**, **71**) of fire resistant thermoset plastic preferably in the form of a paste. The panels (**10**) have use in a wide range of applications including in a blast mitigating overhead storage bin (**100**). The storage bin (**100**) includes a main body portion (**133**) defining a storage area formed from composite unarmored and armored panel segments (**137**, **138**; **128-132**). The unarmored and armored panel segments (**137**, **138**; **128-132**) share first and second shells (**14**, **15**) to form an integral main body portion, with the armored panel segments (**128-132**) providing blast protection between the storage area and a wall (**125**) of an airplane cabin (**120**).

26 Claims, 3 Drawing Sheets



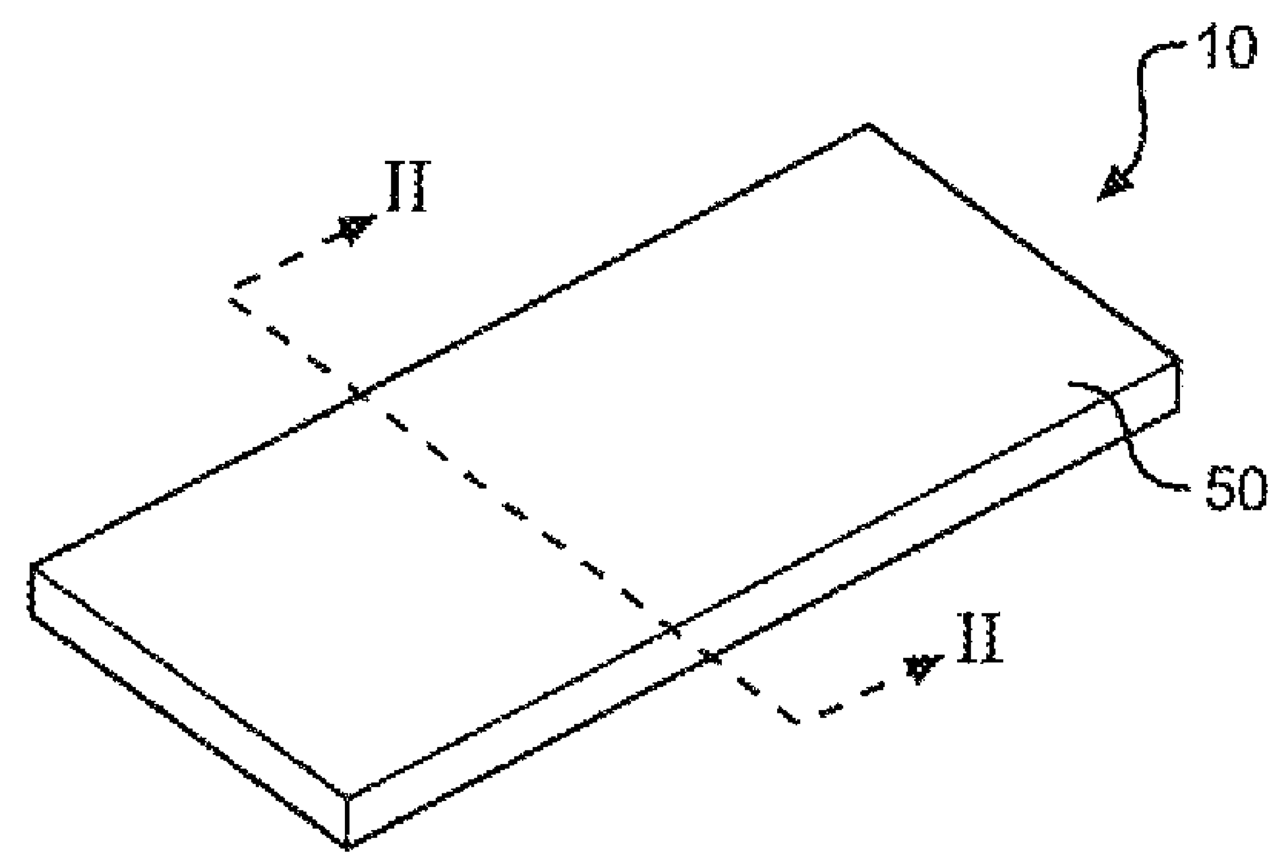


FIG. 1

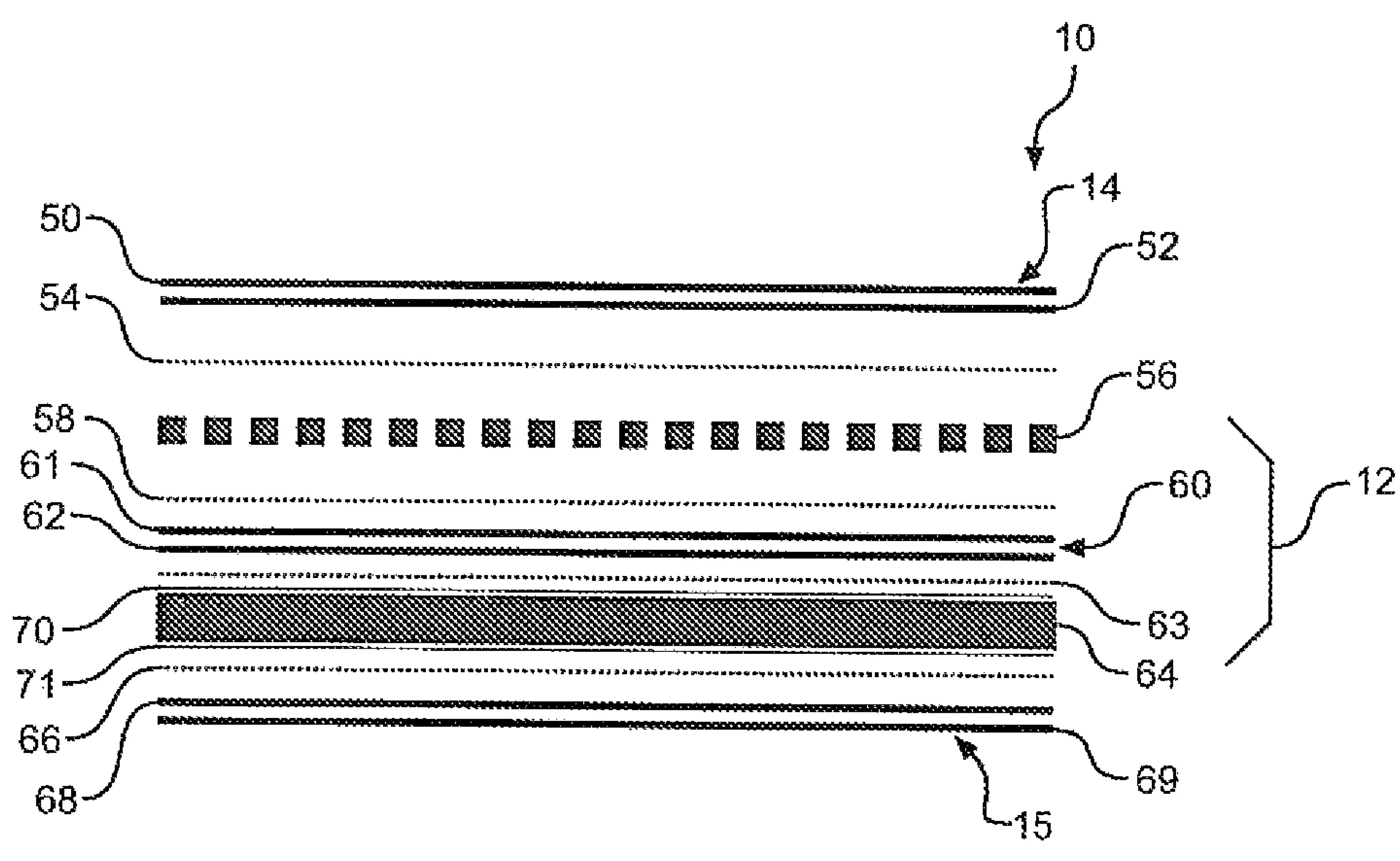


FIG. 2

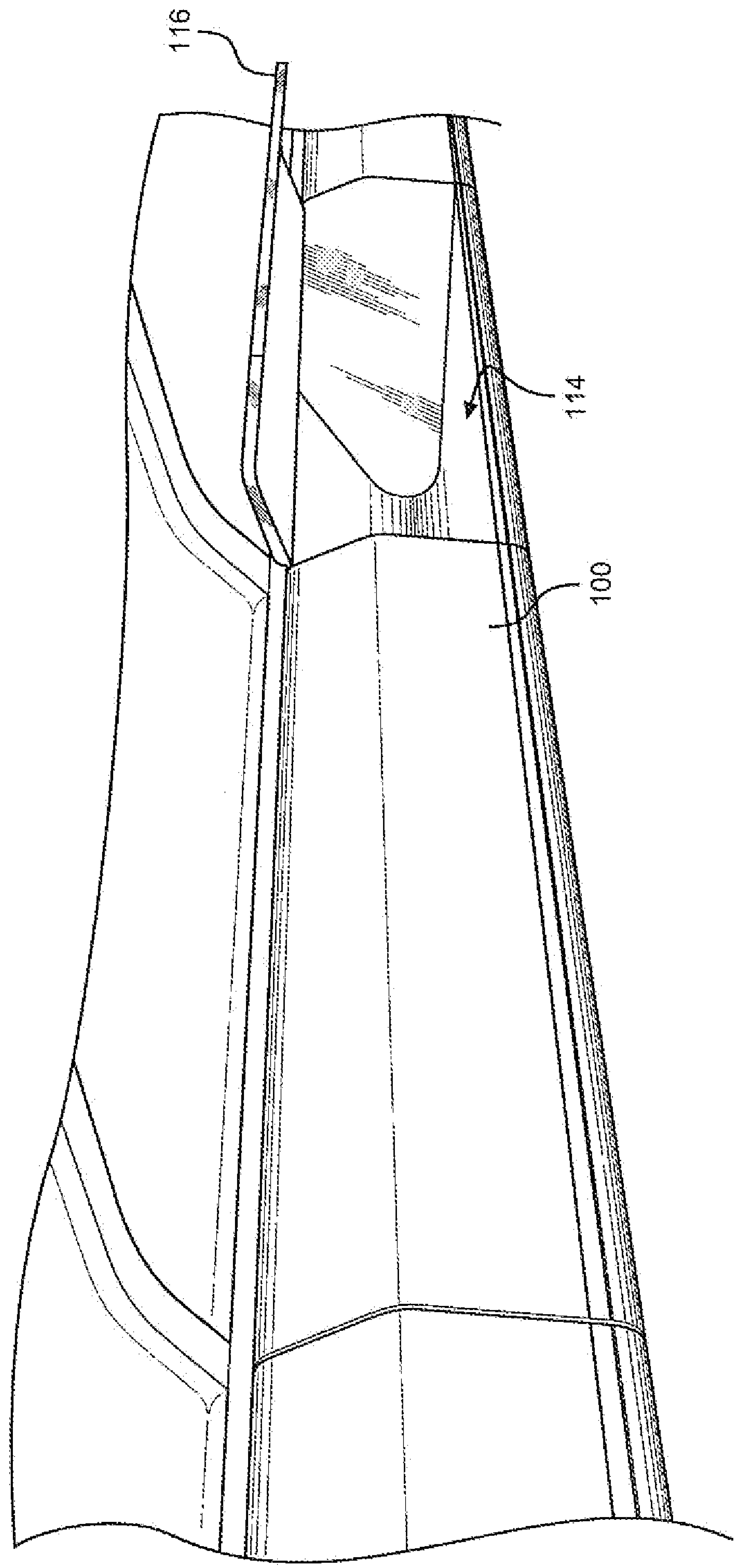


FIG. 3

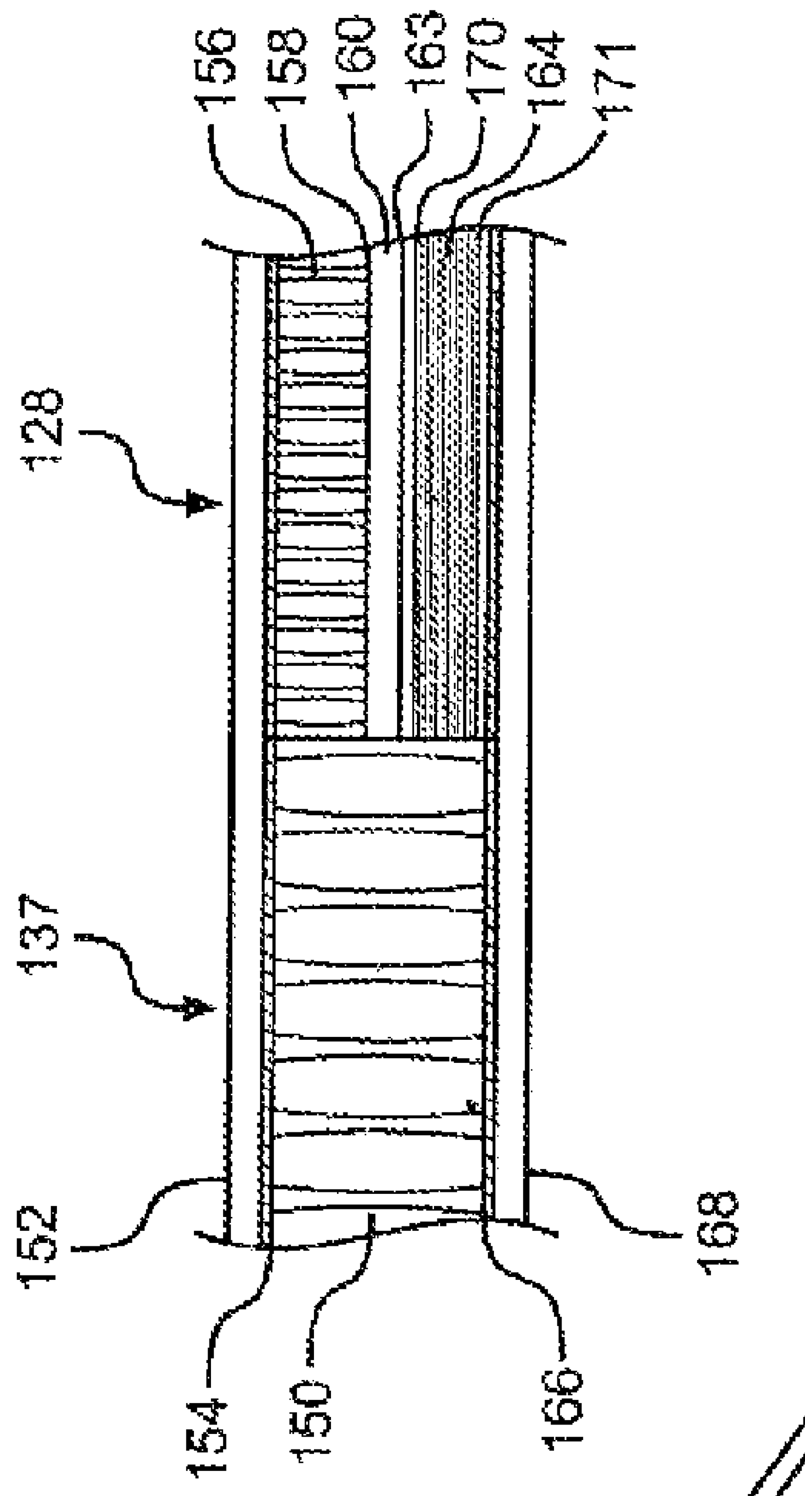

156
158
160
163
170
164
171
128
137
152
154
150
166
168

FIG. 4B

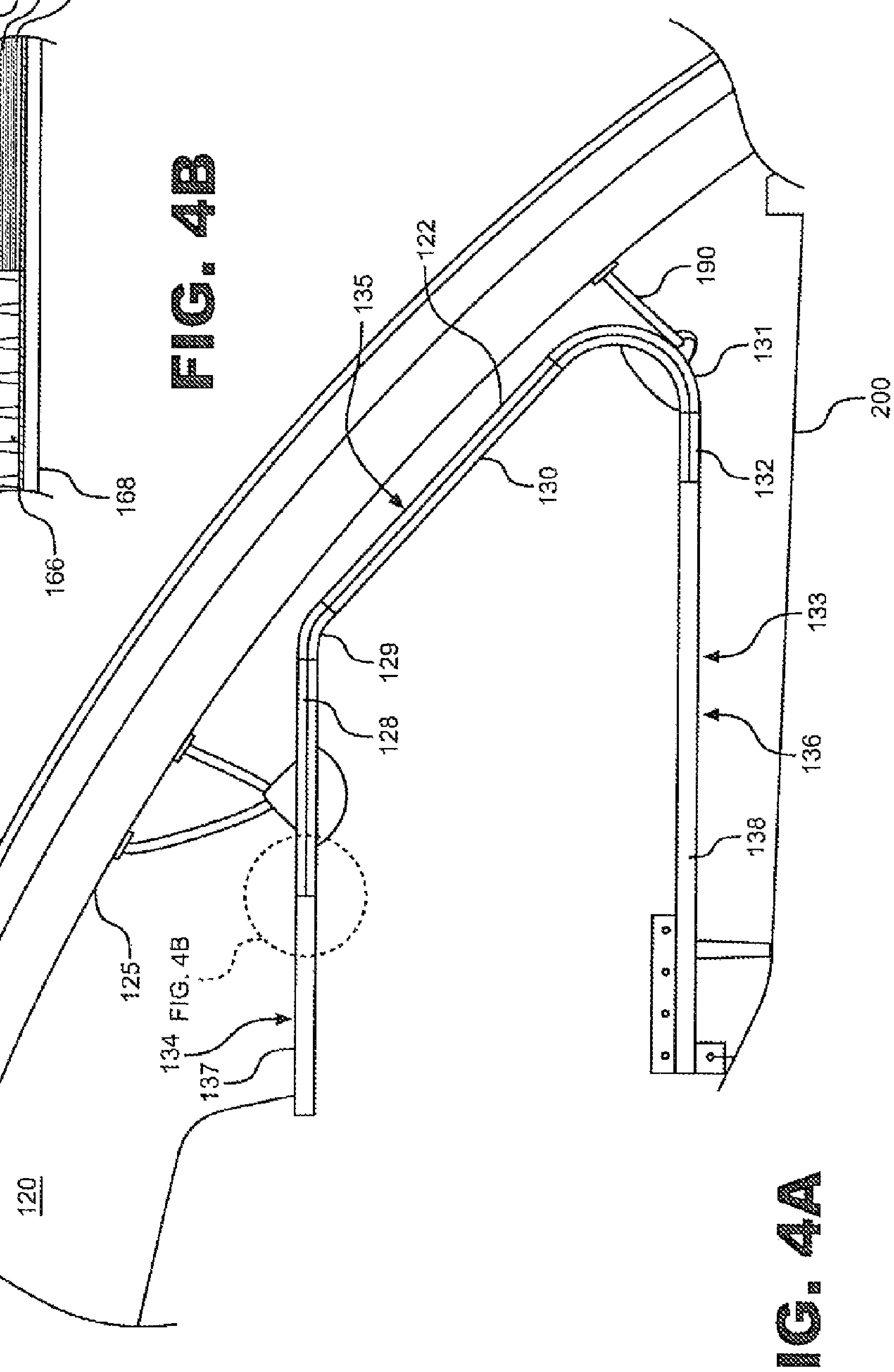

135
122
190
131
200
130
132
133
136
129
128
138
125
FIG. 4B
134
137
120

FIG. 4A

LIGHTWEIGHT BLAST MITIGATING COMPOSITE PANEL

CROSS-REFERENCE TO RELATED APPLICATIONS

This application represents a National Stage application of PCT/US2009/042677 entitled "Lightweight Blast Mitigating Composite Panel" filed May 4, 2009, pending, which claims priority of U.S. Provisional Patent Application Ser. No. 61/071,516, filed May 2, 2008, entitled "Aircraft Overhead Storage Bin" and U.S. Provisional Patent Application Ser. No. 61/071,517, filed May 2, 2008 entitled "Lightweight Blast Mitigating Composite Panel".

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

The present invention was developed under TSA/TSL Contract No. DTFACT-03-C-00042. Therefore, the U.S. Government has certain rights to the invention.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention pertains to the art of protective panels and, more specifically, to lightweight blast mitigating composite panels.

2. Discussion of the Prior Art

Blast mitigation can be achieved by numerous methods including the use of structural elements such as composite armor. In general, composite armor comprises a system of materials in which ultra high molecular weight polyethylene (UHMWPE) fibers are arranged within a matrix to form a core that is subsequently encased in some form of outer shell such as ceramic or fiberglass. The core and shell may be further surrounded by a protective sleeve or case. A limiting factor of such armors is the ability of the UHMWPE fibers to delocalize or disperse a blast load over the matrix.

One area where blast mitigation is increasingly utilized is in transportation applications. It is an unfortunate fact that terrorist threats to public transportation have increased in recent times. Bombs of various sorts have been utilized by terrorists in a variety of situations and pose a particular threat to in-flight aircraft. Despite an increase in security procedures and the use of explosives detecting equipment, bombs have still occasionally found their way aboard aircraft. Bombs may be smuggled into an aircraft in carry-on luggage or other parcels that are stored and carried in the overhead storage bins of the aircraft. Because of regulatory requirements, as well as practical considerations, overhead storage bins have certain size and weight limitations.

Based on the above, there exists a need for a lightweight blast mitigating composite panel which is adapted to protect against damage from an explosion and constructed from materials which are cost-effective. In particular, there is seen to exist a need for a lightweight panel which can be utilized in overhead storage bins to protect against damage from an explosion from within the bin.

SUMMARY OF THE INVENTION

The present invention is directed to a lightweight blast mitigating composite panel. More specifically, a composite panel includes multiple layers incorporating ultra high molecular weight polyethylene (UHMWPE) fibers as a primary strength component, a honeycomb layer, flame resistant thermoset adhesive layers applied on either side of the UHMWPE layer, and a fiber reinforcing layer applied on either side of the flame resistant thermoset layers. These composite layers form a core which is then encased in an outer fiberglass shell. The flame resistant thermoset adhesive layers provide for increased adhesion between the UHMWPE core and the high strength reinforcing fibers. The overall combined layering results in a panel having increased dynamic stiffness and the ability to disperse/distribute localized blast loads. The panels have numerous applications, including in the manufacturing of blast mitigating storage bins for aircraft. More specifically, a blast mitigating storage bin of the present invention includes integrated unarmored and armored portions covered by continuous upper and lower shells. The storage bin is lightweight and can replace a standard overhead storage bin in the cabin of an aircraft with no outward change in appearance or function, while the overall combined layering results in a panel having increased dynamic stiffness and the ability to disperse/distribute localized blast loads.

Additional objects, features and advantages of the present invention will become more readily apparent from the following detailed description of preferred embodiments when taken in conjunction with the drawings wherein like reference numerals refer to corresponding parts in the several views.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a lightweight blast mitigating composite panel of the present invention;

FIG. **2** is a representative cross-sectional view of the lightweight blast mitigating composite panel of FIG. **1**;

FIG. **3** is a perspective view of a hardened overhead luggage bin of the present invention;

FIG. **4**A is a partial cross-sectional side view of the bin of FIG. **3** without a door mounted thereon; and

FIG. **4**B is an enlarged cross-sectional view of a portion of the bin of FIG. **4**A incorporating lightweight blast mitigating composite panels of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With initial reference to FIG. **1**, a lightweight blast mitigating composite panel is generally indicated at **10**. As will be detailed more fully below, panel **10** is constructed in a manner which provides for enhanced blast absorption, suppression and mitigation capabilities verses known composite panels employed for similar purposes. In general, panel **10** has various potential uses, including military, law enforcement, transportation and storm management fields.

Turning to FIG. **2**, panel **10** incorporates ultra high molecular weight polyethylene (UHMWPE) fibers within a matrix to form a core **12** that is subsequently encased by first and second outer shells indicated at **14** and **15**. Core **12** and shells **14** and **15** may be further surrounded by a protective sleeve or case (not shown).

More specifically, as depicted in FIG. **2**, composite panel **10** includes outer shell **14** which is preferably comprised of reinforcing layers **50** and **52**, a first flame-resistant adhesive layer **54**, an intermediate, preferably honeycomb layer **56**, a second flame-resistant adhesive layer **58**, a first fiber reinforcing layer **60** comprised of reinforcing layers **61** and **62**, a third flame-resistant adhesive layer **63**, a UHMWPE layer **64**, a fourth flame-resistant adhesive layer **66**, and second outer shell **15** comprised of fiber reinforcing layers **68** and **69**. In accordance with the invention, UHMWPE layer **64** is coated on each side with respective thermoset flame resistant plastic coating **70** and **71** in the form of a thin flame resistant paste. UHMWPE layer **64** is preferably Dyneema® or Spectra®, while honeycomb layer **56** is preferably Nomex®.

In accordance with the first embodiment, the lightweight armored panel of the present invention has the following characteristics: first outer shell **14** includes first and second reinforcing layers **50** and **52**, each comprised of an E-glass/phenolic facing having a thickness of approximately 0.016 inches. Second outer shell **15** includes first and second fiber reinforcing layers **68** and **69** in the form of uni-directional carbon fiber/phenolic facings having a thickness of approximately 0.02 inches each. Likewise, first, interior reinforcing layer **60** includes first and second reinforcing layers **61** and **62** in the form of uni-directional carbon fiber/phenolic facings having a thickness of approximately 0.02 inches each. Flame resistant adhesive layer **54** extends between honeycomb layer **56** and first outer shell **14**, and flame resistant adhesive layer **58** extends between honeycomb layer **56** and reinforcing layer **60**. UHMWPE layer **64** includes thermoset flame resistant upper and lower plastic coatings **70** and **71**, wherein layer **64** has an overall thickness in the order of 0.2 inches, most preferably approximately 0.214 inches. Additional flame resistant adhesive layers **63** and **66** having a thickness of approximately 0.005 inches adhere UHMWPE layer **64** to respective second outer shell **15** and first reinforcing layer **60**. This first configuration results in a lightweight composite panel having an overall thickness in the order to 0.6-0.7 inches, preferably approximately 0.671 inches. Details of this first embodiment, which exhibits an advantageous strength to weight ratio, are summarized in Table 1 below.

TABLE 1

Material systems for armored segments

System Designation	Material	Thickness (inch)
MLMC-F	1583 E-glass/phenolic facing	0.016
	1583 E-glass/phenolic facing	0.016
	L-310 phenolic adhesive	0.005
	Nomex ® honeycomb	0.365
	L-310 phenolic adhesive	0.005
	UNI carbon fiber/phenolic facing	0.02
	L-310 phenolic adhesive	0.005
	Dyneema ® HB25, 36 ply (w FR coating, Low Pressure Press)	0.214
	L-310 phenolic adhesive	0.005
	UNI carbon fiber/phenolic facing	0.02
	Total	0.671

One application of the lightweight blast mitigating panel **10** of the present invention is in the production of blast mitigating storage devices. With reference to FIG. **3**, a blast mitigating overhead storage bin constructed in accordance with the present invention is indicated at **100**. In general, storage bin **100** includes multiple storage compartments **114** and multiple hinged doors **116** adapted to seal the respective storage compartments **114**. With reference to FIG. **4**A, storage bin **100** is shown installed inside an aircraft cabin indicated at **120** in a manner known in the art, with a back outer wall **122** of storage bin **100** adjacent an inner wall **125** of aircraft cabin **120**. Typical overhead storage bins are manufactured from lightweight composite materials which are vulnerable to explosive devices. As depicted in FIG. **4**A, storage bin **100** incorporates blast-mitigating composite panels of the present invention in the form of armored panel segments **128-132**, which provide sufficient ballistic and blast resistance to contain the effects of an explosive device. More specifically, storage bin **100** includes a main body portion **133** including an upper section **134**, a back section **135**, and a lower section **136** substantially parallel to upper section **134**. In a preferred embodiment shown, upper section **134** is constituted by an unarmored top segment **137** and armored top panel segment **128**. Similarly, lower section **136** is constituted by an unarmored bottom segment **138** and armored bottom panel segment **132**, while back section **135** is constituted by armored panel segments **129-131**. Each of the upper, back and lower sections **134-136** form an integral main body portion **133** as will be discussed in more detail below.

With particular reference to FIG. **4**B, unarmored top and base segments **137** and **138** are preferably formed from composite materials typical of standard overhead storage bins. For example, unarmored top segment **137** is shown to include a core **150** of Nomex® honeycomb material, a first shell **152** of 1583 E-glass/phenolic facing adhered to core **150** with a fire or flame resistant adhesive **154** such as a L-310 phenolic adhesive film made by J. D. Lincoln, Inc., and a second shell **168** of S-glass phenolic prepreg adhered to core **150** with a flame resistant adhesive **166** such as a L-310 phenolic adhesive film. Armored panel segments **128-132** are integrally formed with unarmored top and base segments **137** and **138**. More specifically, as demonstrated by unarmored top segment **137** and armored panel segment **128** in FIG. **4**B, armored panel segment **128** includes the same first and second shells **152** and **168** as unarmored top segment **137**. However, as depicted in FIG. **4**B, the inner portion of armored panel segments **128-132** include a honeycomb layer **156**, a first reinforcement layer **160** of S-glass phenolic prepreg, an ultra high molecular weight polyethylene (UHMWPE) fiber layer **164**, a flame resistant thermoset plastic adhesive layer **163** between UHMWPE layer **164** and first reinforcement layer **160**, and a flame resistant thermoset plastic adhesive layer **158** between honeycomb layer **156** and first reinforcement layer **160**. Further, adhesive layer **154** extends between first shell **152** and honeycomb layer **156**, while adhesive layer **166** extends between second shell **168** and UHMWPE layer **164**.

In a preferred embodiment, UHMWPE fiber layer **164** is comprised of long chain polyethylene having molecular weights ranging from 3 to 6 million. However, in general, molecular weights above 500 thousand would be considered ultra high and functional in accordance with the invention. Still, a preferred molecular weight range is greater than 1 million and, most preferred is the 3-6 million weight range. In accordance with the present invention, UHMWPE layer **164** is coated on upper and lower sides with a fire resistant thermoset plastic coating indicated at **170** and **171** in the form of a thin flame resistant paste. Honeycomb layer **156** is preferably Nomex®.

Preferably, lightweight panel portions **128-132** utilized in blast mitigating overhead storage bin **100** include the following characteristics: first shell **152** comprises a single layer of E-glass/phenolic facing having a thickness of approximately 0.014 inches; flame resistant adhesive layers **154**, **158**, **163** and **166** comprise phenolic adhesive layers having a thickness of approximately 0.005 inches; and first fiber reinforcing layer **160** and second shell **168** comprise S-glass phenolic prepregs having a thickness of approximately 0.019 inches. In this embodiment, Nomex® honeycomb layer **156** has a thickness of approximately 0.365 inches and Dyneema® UHMWPE layer **164** has a thickness of approximately 0.156 inches, with each flame resistant thermoset coating **170** and **171** having a thickness of approximately 0.010 inches. This first configuration results in thin, armored sections **128-132**, having an overall thickness of approximately 0.613 inches and an overall weight of approximately 1.59 lbs/ft^2. Details of this second, strong composite embodiment of the lightweight blast mitigating composite panels of the present invention are summarized in Table 2 below.

TABLE 2

Material System for armored segments.		
Material System	Thickness (inch)	Specific Weigh (lbs/ft2)
APF1114/1583 E-glass/phenolic	0.014	0.1466
L-310 phenolic adhesive (green film)	0.005	0.0225
APH1/8 3.0 lb Nomex ® honeycomb	0.365	0.0913
L-310 phenolic adhesive (green film)	0.005	0.0225
AGY S-glass Phenolic Prepreg	0.019	0.1937
L-310 phenolic adhesive (green film)	0.005	0.0225
FR Coating	0.010	0.0404
Dyneema ®	0.1563	0.7966
FR Coating	0.010	0.0404
L-310 phenolic adhesive (green film)	0.005	0.0225
AGY S-glass Phenolic Prepreg	0.019	0.1937
Total	0.613	1.5926

Referring back to FIG. **4**A, armored panel segments **128-132** are positioned such that inner wall **125** of aircraft cabin **120** will be protected from any blast originating inside storage compartments **114**. Further, armored panel segments **128-132** protect attachment devices such as rackets, turnbuckles or attachment tie-rods **190**, thereby preventing these components from becoming secondary fragments in the event of an explosion. Advantageously, storage bin **100** of the present invention may replace standard overhead luggage bins with, no outward change in appearance or storage function. Although storage bin **100** may have a slightly increased weight, the effects will be minimal. In a preferred embodiment, storage bin **100** has a capacity of greater than 1.75 to 2.0 pounds (lbs) per linear inch or 10 lbs per cubic foot, and includes a height of 12.10 to 13.14 inches, a bottom length of 25.59 to 30.63 inches and a top length of 11.40 to 15.15 inches. Passengers need not exert more than 50 lbs$_f$ to close a fully loaded bin **100** and 20 lbs$_f$ to open an empty bin **100**, and storage bin **100** can withstand a hanging load of 300 lbs based on a passenger abuse test. Further, in accordance with standard requirements, storage bin **100** can be adapted to be utilized with passenger service units, such as a call button, lights, and the like (not shown) on an overhead panel **200**. Vibration and fatigue of storage bin **100** does not interfere with the performance of the plane, particularly sensitive electronic parts. It should be noted that composite assemblies of different configurations (i.e., armored and non-armored) do not represent any additional difficulties in fabrication, production or assembly, keeping in mind that current bins are typically assembled from panels and are composed of panels of varying properties.

In accordance with the invention, it has been surprisingly found that the inclusion of the flame resistant thermoset plastic layers such as **70**, **71** and **170**, **171**, dramatically enhances the blast absorption, suppression and mitigation capabilities of typical UHMWPE type shields by up to 4 times verses corresponding structure without the flame resistant thermoset plastic layers. Although the fire resistant layers' usual purpose is fire resistance, it is speculated that the fire resistant layers stiffen the Dyneema® layer enough to allow the stress created by a blast to disperse over a larger area. This may be due to the flame resistant thermoset plastic layers significantly enhancing the adherence of the composite layers to the UHMWPE layer core, be it Dyneema®, Spectra® or the like.

In effect, this configuration increases the stiffness of the core material, which manifests itself into increased distribution of the localized loads resulting in significant improvements in blast performance. This system provides the core material with the required stiffness to absorb blast and ballistic threats. More specifically, composite panels including a coated UHMWPE core were found to perform well under both series 1 and series 2 tests under Section 2.1.2 (Fragmentation/Shock holing) of ISO 6517, Draft Appendix A, while standard panels known in the industry were found to perform at most under series 1 test requirements, as evidenced by the experimental results described below.

EXPERIMENTAL RESULTS

A total of eight sample panels were tested based on requirements set forth in the overhead bin specification Section 2.1.2 (Fragmentation/Shock holing) of ISO 6517, Draft Appendix A. The panels were tested under series 1 and series 2. The tests were conducted at Aberdeen Proving Grounds.

Test #1—Panel Composition No. 1, Series 1

A first 4'×4' panel had an identical composition and thickness to a standard hardened cockpit door supplied by C&D Aerospace, Inc. Specifically, the panel was composed of a 2-ply phenolic/E-glass facesheet, a film epoxy adhesive, a ⅜" Nomex® honeycomb panel treated with phenolic resin, a film epoxy adhesive, a UHMWPE—Dyneema® panel (3⁄16"), a film epoxy adhesive, and a 2-ply phenolic/E-glass facesheet. The panel was 1" thick and had an areal weight of 1.5 lb/sqft. The resin content was between 30-40% within the E-glass facing.

Test Procedure: The panel was mounted to a test fixture with 3 soft-sided suitcases, the charge suitcase was in the center. The contents, weight and composition of the charge bag and adjacent bags were documented to maintain consistency from test to test. Charge size and placement were in accordance with the requirements of overhead bin specification Section 2.1.2 of ISO 6517, Draft Appendix A, series 1. Instrumentation of the test was limited to still photograph documentation.

Test Results: Criteria for determining if a panel was deemed to have passed the test was a visual inspection of the panel post-test for signs of rupture at panel center due to impulsive loading. Panel pull-through at edges of bolted connections was not a criteria for shock hole failure. The panel did not perforate. On the outside panel, there was a tear in the 2 E-glass plies that measured 39" horizontally and 40" diagonally downwards. There were multiple tears between 15" and 41" to the E-glass (2 plies) and a 16"×18" hole in the honeycomb. On the inside panel, there was a 42" horizontal tear to the E-glass and a 10½"×18½" hole in the honeycomb. There was no hole in the Dyneema®. There was fragment damage to the inside face measuring 3"×3¼" and 2½×1½". There was minor charring to the panel and the dome deformation measured 4⅜". There was delamination near the center of the panel. The E-glass and honeycomb delaminated from the Dyneema®.

This panel passed under the requirements of overhead bin specification Section 2.1.2 (Fragmentation/Shockholing) of ISO 6517, Draft Appendix A, series 1.

Test #2—Panel Composition No. 1, Series 1

The panel submitted for test #2 was identical in construction and composition to the panel submitted in test #1.

Test Procedure: The panel was mounted in the test fixture and the bags were prepared and oriented identically to the manner used in test #1. The explosive charge weight, composition, initiation procedure and charge standoff were identical to the procedures noted in test #1.

Test Results: The panel did not perforate. On the outside panel, there was a tear that measured 30" horizontally and 37" vertically to the E-glass (2 plies). There were tears between 20" and 42" to the 2 plies of the E-glass and an 18" (horizontal)×11" (vertical) tear to the Nomex®. On the inside panel there was 30" (horizontal) and 37" (vertical) tears to the E-glass—2 plies and an 11" (horizontal)×8" (vertical) tear to the Nomex®. There was no hole in the Dyneema®. There was fragment damage to the inside face with a 1" hole and minor charring to the panel. The panel did not separate from the fixture. The dome deformation measured 2". There was delamination to the E-glass and honeycomb near the center of the panel.

This panel passed under the requirements to overhead bin specification Section 2.1.2 (Fragmentation/Shockholing) of ISO 6517, Draft Appendix A, series 1. By passing 2 successive series 1 tests, this panel design completely met series 1 shock hole requirements.

Test #3—Panel Composition No. 1, Series 2

The panel submitted for test #3 was identical in construction and composition to the panels submitted in tests #1 and #2.

Test Procedure: The panel was mounted in the test fixture and the bags were prepared and oriented identically to the manner used in tests #1 and #2.

Test Results: The panel perforated. On the outside panel, there were tears that measured between 44" and 16" to the E-glass (2 plies) and there was a 12"×11" hole in the honeycomb. On the inside panel there was a 17"×20" tear to the E-glass (2 plies) and a 12"×11" hole in the honeycomb. There was a hole in the Dyneema® that measured 6"×6". The panel did not separate from the fixture. There was also delamination near the central region. The panel did not burn and there was no fragment damage.

This panel failed under the requirements to overhead bin specification Section 2.1.2 (Fragmentation/Shockholing) of ISO 6517, Draft Appendix A, series 2.

Test #4—Panel Composition No. 2, Series 2

The panel submitted for test #4 was nearly identical in construction and composition to the panels submitted in tests 1-3, the only difference was the inclusion of a fire retardant (FR) layer placed on both sides and directly in contact with the Dyneema® layer. The FR layers were comprised of a thermosetting glue made by Composix in Newark, Ohio, having a thickness of approximately 0.060".

Test Procedure: The panel was mounted in the test fixture and the bags were prepared and oriented identically to the manner used in Tests 1-3.

Test Results: The panel did not perforate. On the outside panel, there was a tear in the 2-ply E-glass that measured 37" (horizontally) and 32" (vertically) and there was a 23"×15" hole in the honeycomb. On the inside panel there was a 9"×7" hole in the 2-ply E-glass and a 9"×12" hole in the Nomex®. There was delamination in the central region to the Dyneema®. The panel did not burn and there was no fragment damage. The dome deformation measured 1⅜".

This panel passed under the requirements to overhead bin specification Section 2.1.2 (Fragmentation/Shockholing) of ISO 6517, Draft Appendix A, series 2.

Test #5—Panel Composition No. 1, Series 2

The panel submitted for test #5 was identical in construction and composition to the panels submitted in tests 1-3.

Test Procedure: The panel was mounted in the test fixture and the bags were prepared and oriented identically to the manner used in tests 1-4.

Test Results: The panel perforated. On the outside panel, there were tears in the 2-ply E-glass that measured between 18" and 40" and a 9"×11" hole in the Nomex®. On the inside panel there was an 8"×10" hole in the 2-ply E-glass and an 8"×11" hole in the Nomex®. There was a 3"×2" hole in the Dyneema®. There was delamination in the central region to the E-glass and Nomex® from the Dyneema®. The dome deformation measured 4½". The panel did not burn and there was no fragment damage.

This panel failed under the requirements to overhead bin specification Section 2.1.2 (Fragmentation/Shockholing) of ISO 6517, Draft Appendix A, series 2.

Test #6—Panel Composition No. 3, Series 2

A 4'×4' panel sample was submitted having 6 plies composed of S2-glass/phenolic laminate, 0/90 layup. The panel was ⅛" thick and had an areal weight of 1.30 lb/sqft. The resin content was about 32%-35%.

Test Procedure: The panel was mounted to the test fixture with 3 soft-sided suitcases, the charge suitcase was in the center. The contents, weight and composition of the charge bag and adjacent bags were documented to maintain consistency from test to test. Charge size and placement were in accordance with the requirements to overhead bin specification Section 2.12 (Fragmentation/Shockholing) of ISO 6517, Draft Appendix A, series 1 and series 2. Instrumentation of the test was limited to still photograph documentation.

Test Results: Criteria for determining if a panel was deemed to have passed the test was a visual inspection of the panel post-test for signs of rupture at panel center due to impulsive loading. Panel pull-through at edges of bolted connections was not a criteria for shock hole failure. The panel perforated. On the outside and inside of the panel, there was delamination throughout most of the panel. There was a hole that measured 6" and all 6 plies were penetrated. There was no fragment damage and minor charring to the panel.

This panel failed under the requirements to overhead bin specification Section 2.1.2 (Fragmentation/Shockholing) of ISO 6517, Draft Appendix A, series 2.

Test #7—Panel Composition No. 3, Series 2

The panel submitted for test #6 was identical in construction and composition to the panel submitted in test #5.

Test Procedure: The panel was mounted in the test fixture and the bags were prepared and oriented identically to the manner used in test #5. The explosive charge weight, composition, initiation procedure and charge standoff were identical to the procedures noted in test #5.

Test Results: The panel perforated. There was delamination of 6 plies in and around the central hole and multiple tears extending inward from the bolt holes approximately 15" long. There was a hole that measured 5". There was one small fragment damage portion with partial penetration. There was also minor charring to the panel.

This panel failed under the requirements to overhead bin specification Section 2.1.2 (Fragmentation/Shockholing) of ISO 6517, Draft Appendix A, series 2.

Test #8—Panel Composition No. 3, Series 1

The panel submitted for test #7 was identical in construction and composition to the panels submitted in test #'s 5 and 6.

Test Procedure: The panel was mounted in the test fixture and the bags were prepared and oriented identically to the manner used in test #5 and #6.

Test Results: The panel perforated. There was delamination throughout the panel. There were multiple tears to the inside face extending inward form the bolt holes approximately 10". There was a hole that measured 9" vertically and 6" horizontally. There was no fragment damage and minor charring to the panel.

This panel failed under the requirements to overhead bin specification Section 2.1.2 (Fragmentation/Shockholing) of ISO 6517, Draft Appendix A, series 1.

Although described with reference to preferred embodiments of the invention, it should be readily understood that various changes and/or modifications can be made to the invention without departing from the spirit thereof. For instance, although main body portion **133** of overhead bin **100** is shown including five armored panel portions **128-132**, it should be understood that various configurations utilizing different numbers of armored panels may be utilized without departing from the present invention. Additionally, although the disclosed embodiments refer to panels having a final thickness of approximately 0.613 and 0.671 inches, it should be understood that the general and specific thicknesses of each layer can be tailored to a desired application and the threat present in that particular application. Furthermore, although honeycomb layers **56**, **156** are shown, honeycomb layers **56**, **156** may not be necessary for every application of the armored panels of the present invention. Although S-glass and E-glass have been discussed above for use in the armored panel, other fiberglass products could be employed. Particularly preferred is S-2 Glass® made by AGY Holding Corporation.

Advantageously, the present invention provides a lightweight panel without the need for any metal, ceramic or other hard and difficult to process materials. The panel of the present invention can be shaped to limited curvatures and formed into components and panels to conform to existing configurations or replace existing structural panels. It should be readily understood that the armored panels of the present invention, in addition to having applications in baggage compartments and containers, can have applications including: military body or vehicle armor; homeland security, anti-terrorism and personal security fields; automotive, shipping and aerospace vehicles; and storm management. More specifically, the present invention may have use in load bearing structures, lightweight walls, explosive blow-out containment or mitigation walls or barriers in building construction, cargo applications, monuments, flooring, doors, and auxiliary panels, for example. In any case, the invention is only intended to be limited to the scope of the following claims.

What is claimed is:

1. A lightweight blast mitigating composite panel comprising:

a first glass composite shell;

an intermediate layer;

a first flame resistant adhesive layer interposed between and adhering the intermediate layer to the first glass composite shell;

a first reinforcing layer;

a second flame resistant adhesive layer interposed between and adhering the first reinforcing layer to the intermediate layer;

an ultra high molecular weight polyethylene fiber layer including an upper coating of fire resistant thermoset plastic and a lower coating of fire resistant thermoset plastic;

a third flame resistant adhesive layer interposed between and adhering the ultra high molecular weight polyethylene fiber layer to the first reinforcing layer;

a second glass composite shell; and

a fourth flame resistant adhesive layer interposed between and adhering the ultra high molecular weight polyethylene fiber layer to the second glass composite shell.

2. The lightweight blast mitigating composite panel of claim **1**, wherein the intermediate layer constitutes a honeycomb layer.

3. The lightweight blast mitigating composite panel of claim **1**, wherein the first glass composite shell is constituted by an E-glass and phenolic composite.

4. The lightweight blast mitigating composite panel of claim **1**, wherein the first reinforcing layer is constituted by an S-glass and phenolic composite.

5. The lightweight blast mitigating composite panel of claim **1**, wherein the panel has a thickness in the order of 0.6 inches.

6. The lightweight blast mitigating composite panel of claim **1**, wherein the first glass composite shell is constituted by two E-glass and phenolic composite sheets.

7. The lightweight blast mitigating composite panel of claim **6**, wherein the first reinforcing layer is in the form of a uni-directional carbon fiber and phenolic facing.

8. The lightweight blast mitigating composite panel of claim **1**, wherein:

the intermediate layer is directly adhered to the first glass composite shell;

the first reinforcing layer is directly adhered to the intermediate layer;

the ultra high molecular weight polyethylene fiber layer is directly adhered to the first reinforcing layer; and

the ultra high molecular weight polyethylene fiber layer is directly adhered to the second glass composite shell.

9. The lightweight blast mitigating composite panel of claim **1** wherein:

the first reinforcing layer is formed of a material different from the ultra high molecular weight polyethylene fiber layer.

10. A blast mitigating storage bin for an aircraft comprising:

a main body portion including an upper section, a back section and a lower section, wherein the upper section, back section and lower section define a storage area, and wherein the main body portion is constituted by at least a first unarmored panel and a first lightweight blast mitigating composite panel, the first lightweight blast mitigating composite panel including:

a first glass composite shell;

an intermediate layer;

a first flame resistant adhesive layer interposed between and adhering the intermediate layer to the first glass composite shell;

a first reinforcing layer;

a second flame resistant adhesive layer interposed between and adhering the first reinforcing layer to the intermediate layer;

an ultra high molecular weight polyethylene fiber layer including an upper coating of fire resistant thermoset plastic and a lower coating of fire resistant thermoset plastic;

a third flame resistant adhesive layer interposed between and adhering the ultra high molecular weight polyethylene fiber layer to the first reinforcing layer;

a second glass composite shell; and

a fourth flame resistant adhesive layer interposed between and adhering the ultra high molecular weight polyethylene fiber layer to the second glass composite shell.

11. The blast mitigating storage bin of claim 10, wherein the intermediate layer constitutes a honeycomb layer.

12. The blast mitigating storage bin of claim 10, wherein the first glass composite shell is constituted by an E-glass and phenolic composite.

13. The blast mitigating storage bin of claim 10, wherein the first reinforcing layer is constituted by an S-glass and phenolic composite.

14. The blast mitigating storage bin of claim 10, wherein first lightweight blast mitigating composite panel has a thickness in the order of 0.6 inches.

15. The blast mitigating storage bin of claim 10, wherein the first glass composite shell is constituted by first and second E-glass and phenolic composite sheets.

16. The blast mitigating storage bin of claim 15, wherein the first reinforcing layer is constituted by a uni-directional carbon fiber and phenolic facing.

17. The blast mitigating storage bin of claim 10, wherein the first unarmored panel comprises a honeycomb layer interconnected between the first and second glass composite shells such that the first and second glass composite shells are common to the unarmored panel and the first lightweight blast mitigating composite panel.

18. The blast mitigating storage bin of claim 17, wherein the honeycomb layer is affixed to the first and second glass composite shells by the first and fourth flame resistant adhesive layers respectively.

19. The blast mitigating storage bin of claim 10, wherein the main body portion additionally comprises second and third lightweight blast mitigating composite panels constructed as the first lightweight blast mitigating composite panel.

20. The blast mitigating storage bin of claim 19, wherein the first lightweight blast mitigating composite panel defines part of the upper section of the main body portion, the second lightweight blast mitigating composite panel defines at least part of the back section of the main body portion, and the third lightweight blast mitigating composite panel defines part of the lower section of the main body portion such that the first, second and third lightweight blast mitigating composite panels provide blast protection between the storage area of the main body portion and a wall of an airplane when the storage bin is mounted to a wall of an airplane.

21. The blast mitigating storage bin of claim 10, further comprising at least one attachment device connected to an outer wall of the main body portion at the first lightweight blast mitigating composite panel such that the attachment device is protected by the first lightweight blast mitigating composite panel from any explosion originating in the storage area of the storage bin.

22. A method of forming a lightweight blast mitigating panel comprising:

adhering a first glass composite shell layer to an intermediate layer with a first flame resistant adhesive layer interposed between the first glass composite shell layer and the intermediate layer;

adhering a first reinforcing layer to the intermediate layer with a second flame resistant adhesive layer interposed between the first reinforcing layer and the intermediate layer;

adhering an ultra high molecular weight polyethylene fiber layer including an upper coating of fire resistant thermoset plastic and a lower coating of fire resistant thermoset plastic to the first reinforcing layer with a third flame resistant adhesive layer interposed between the ultra high molecular weight polyethylene fiber layer and the first reinforcing layer; and

adhering a second glass composite shell layer to the ultra high molecular weight polyethylene fiber layer with a fourth flame resistant adhesive layer interposed between the second glass composite shell layer and the ultra high molecular weight polyethylene fiber layer.

23. The method of claim 22, further comprising: providing the intermediate layer as a honeycomb layer.

24. The method of claim 22, further comprising: forming a blast mitigating aircraft overhead storage bin by creating a main body portion including an upper section, a back section and a lower section, wherein the upper section, back section and lower section define a storage area and wherein the main body is constituted by at least a first unarmored panel and the lightweight blast mitigating panel.

25. The method of claim 22, wherein:

adhering the first glass composite shell layer to the intermediate layer includes directly adhering the first glass composite shell layer to the intermediate layer;

adhering the first reinforcing layer to the intermediate layer includes directly adhering the first reinforcing layer to the intermediate layer;

adhering the ultra high molecular weight polyethylene fiber layer to the first reinforcing layer includes directly adhering the ultra high molecular weight polyethylene fiber layer to the first reinforcing layer; and

adhering the second glass composite shell layer to the ultra high molecular weight polyethylene fiber layer includes directly adhering the second glass composite shell layer to the ultra high molecular weight polyethylene fiber layer.

26. The method of claim 22, wherein adhering the first reinforcing layer to the intermediate layer includes adhering the first reinforcing layer, formed of a material different from the ultra high molecule weight polyethylene fiber layer, to the intermediate layer.

* * * * *